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Research Order #1
Phase I - Progress Report #5

3 May 1954

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OBJECTIVE:

To study and evaluate the factors and components involved in the design of a portable infrared communicator.

GENERAL DATA:

The work to be performed according to Bid Proposal #76-1, Phase I, may be summarized as follows:

A. Evaluation of sources and sensitive elements

B. Determination of beam width requirements and evaluation of "find-operate" systems

C. Study of modulation methods and attendant optical systems

D. Evaluation of power sources

E. Study of required circuit characteristics

The results of these studies will be used as the basis for recommending a system to be developed.

DETAILED DATA:

A. Evaluation of sources and sensitive elements

The primary work on the evaluation of sources was accomplished last month. Work was started on the evaluation of sensitive elements and was limited to a study of lead sulfide cells and methods of evaluating certain classes of infrared detectors.

A brief resume of the work follows.

There is certain information that is of value to any

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worker using lead sulfide cells.

1. Response to black-body radiant energy

2. The time constant

3. Absolute spectral sensitivity

The above three factors fairly well define the characteristics of the cell (response characteristics) which are important in a given application. However, there is yet another factor of importance: the factor or figure of merit. This figure of merit enables one to compare cells and other detectors on a common basis.

Much of what follows is a very condensed summary of articles and publications by R. Clark Jones and other workers in the field of infrared detection. *

Methods of Evaluating Photo-conductive Cells

R. Clark Jones derives at least two equations which are useful in the comparison of photo-conductive cells.

Equation 1 $$D(T,\Lambda) = \frac{A^{\frac{1}{2}}}{P_N}\left(\frac{\Delta f}{f}\right)^{\frac{1}{2}}$$

Where,

D is detectivity in watts,

T IS CELL TEMPERATURE

Λ is spectral description (black-body, monochromatic, etc.),

A is the sensitive area of the cell,

P_N is power (watts) incident upon sensitive area of the

* See Appendix I for references.

cell, that produces a signal voltage equal to noise voltage,

Δf is bandwidth of the amplifier in cps,

f is chopping frequency.

It is apparent that Equation 1 places all detectors on common grounds for purposes of comparison.

There is no simple way* to compare test results in which τ and λ differ, but under the same conditions of τ and λ, useful comparisons can be made.

Equation 2.

$$M = K.\frac{D}{t}$$

Where,

M is factor of merit of the cell,

D is detectivity as defined by Equation 1,

t is time constant of cell for cross-over frequency.

Jones gives the following values for factor of merit (M) for different detectors.

1. Bolometers - Unity) Approximately
2. Thermocouples - Unity)
3. Lead Sulfide (modern) - 350
4. Lead Sulfide (German - World War II) - 32

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* Other than plotting data and using graphical methods of analysis.

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Summary - (The Factor of Merit)

Two cells of different sensitive areas but of equal factor of merit will not necessarily yield equivalent results in a given application. However, if each is optimized, reconstructed for optimum sensitive area and optimum time constant, for a given application, then they will yield equivalent performance.

However, if two cells have different factors of merit and are reconstructed for optimum sensitive areas and time constant for a given application, the signal-to-noise ratio will be in proportion to their factors of merit.

B. Determination of beam width requirements and evaluation of "find-operate" systems

The first test made with the beam width simulators has been completed, and an evaluation follows.

This test required personnel to find a modulated IR point source, the position of which was known only within a field of view ten degrees in azimuth and ten degrees in elevation. The acceptance angle of the receiver was 1/3 degree, hence thirty horizontal scans, each displaced 1/3 degree from the preceeding were required to cover the field thoroughly.

Five trials were performed by each operator, the source being located at a different point in the field for each trial. Only seven people cleared for the project were available as operators, providing thirty-five sets of data.

The operators were given written instructions for performing the test (scanning the pattern), and were placed in total darkness during the test so there would be no attempt to align the units visually. The time required to find the target was recorded for each trial, and the data is given in Appendix II, Table 1.

The average time for all but the three greatest recordings is 1:38. The 13:44.2 recording was discarded, because it was the very first trial and both the operator and instructor were inexperienced. The 12:53.8 reading was the last of one day's session and was repeated the following morning in 1:14, and this latter time was used in the average.

It appeared that sort of a "panic factor" was involved, in that, the longer it took the operator, the more difficult the task became, and the pattern had to be scanned many times. This was most evident in one trial in which the operator, not finding the target, refused to believe that it was in the field. After being convinced of the presence of target, he proceeded to locate it almost immediately.

The most instructive thing learned is that personnel cannot be relied on to train an instrument in darkness accurately to angular increments of 1/3 degree. Therefore, plans are now being made to incorporate in the mounting mechanism an automatic device which will shift the unit vertically thru the proper angular increment at the end of each horizontal scan. With this device it will be possible for the operator to scan the field once completely in about one minute.

From the foregoing it appears that the initial finding operation will proceed in the following manner. Each operator will know according to a predetermined procedure whether he is to receive or transmit first. The one which is to receive will simply repeat over and over his semi-automatic scanning operation, centering about the most probable position of his contact. Upon receiving his contact's signal, he will lock his scanner and switch to transmit. The transmitting operator, however, will not have it so simple. Depending on the angular width of the transmitter beam, he must divide the ten degree square field into which he transmits into a number of sectors, each sector of the same angular dimensions as the transmitter beam.

Now if the transmitter covers a one degree angle, he must potentially divide the 10^{o} field into 100 sectors. Allowing as much as one to two minutes per scan, one complete cycle might take as long as three hours, after which the transmitter would switch to receive.

Conceivably, the receiver operator could find him in the first (most probable) sector, but the transmitter operator, not being aware of this would continue his cycle, and valuable time could be lost. Therefore, it would be required of the transmitter operator to interrupt his cycle every ten or fifteen minutes to perform one receive cycle, just in case the other operator was already aligned. Under favorable conditions contact could be established in fifteen minutes, but if positions were not accurately known, the time might stretch to several hours. This uncertainty could not be tolerated.

The time consuming element lies in the transmitter.

To conserve power and increase security, it is very desirable to maintain a narrow transmitting beam. This latter aspect is evident when it is pointed out that one degree subtends 500 feet at six miles. Thus, a transmitting beam of 10^{o} could easily be intercepted by an airplane flying at an appreciable altitude.

On the other hand the time problem demands that the field of view be divided into as few sectors as possible for the transmission search. This can be accomplished by reducing the field of view, increasing the beam angle or a combination of both factors.

In a previous meeting, 10^{o} ($\pm 5^{o}$) was adopted as the uncertainty in azimuth one station might have with respect to the other. This was extended by us to include the possible elevation error for preliminary calculations. It now appears that this elevation deman may be too restrictive.

The above problem is receiving further consideration at the present time.

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C. Study of modulation methods and attendant optical systems

Further consideration was given to mechanical modulation systems. Calculations were made to determine operating power requirements. In view of the high frequency required (high for a mechanical system), very small motion is allowable, along with small mass in the case of a translatory system and small inertia in the case of a torsional system; otherwise, excessive power will be required to operate the modulator.

Preliminary specifications have been given galvanometer manufacturers for a galvanometer of 5,000 cycles response. Data sufficiently interesting to warrant further consideration of a galvanometer type modulator has been received from two manufacturers.

A major problem is to achieve 100% modulation and still use 100% of the light as against the 50% obtainable in devices using grids. The problem is therefore a combination of modulator and optics.

Various combinations of optics and modulators that might meet the above requirements have been discussed. However, further study will be necessary before proceeding with construction of a system for tests. This work is continuing at the present time.

As a first approximation to a galvanometer type modulator, the following requirements have been established, based on present thinking in regards to the optical system.

Power: 5 watts
Frequency Response: 3,000 cycles, flat
Mirror Size: 4 mm.
Maximum Beam Deflection: 32°
Damping: 64% of critical damping

As a first approximation to a mechanical shutter using translatory motion, it has been suggested that a number of small lenses each focus portions of the light from a large collimating lens. The movement of the mechanical modulator would be small, thereby reducing the required energy. Theoretically the system allows for 100% non-linear modulation and the use of approximately 100% of the light energy.

This system has not been worked out in sufficient detail to warrant an expression of opinion at this time.

D. Evaluation of Power Sources

All equipment ordered for the engine generator set has been received with the exception of the two small alternators. Work has started on the design of a flywheel for the engine. Further study is being made of the muffler system. The noise will have to be reduced by a considerable factor, which calls for a redesign or modification of the muffler.

E. Study of required circuit characteristics

Further study has been made of the infinite clipping circuit. It has been decided to use this electronic circuit in our preliminary work. Although all equipment necessary for testing the system has been ordered, it has not yet arrived.

PROGRAM FOR NEXT INTERVAL

The work on beam width tests will continue. Further consideration will be given to the xenon arcs as a light source. Problems related to the modulation of such a system will be more carefully studied.

Mechanical systems of modulation which are presently under consideration will be worked out along with the study of the optical system. It is also anticipated that some design and experimental work will be done on the electronic system (infinite clipping system).

Report prepared by

Report approved by

Report approved by

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PTS/t

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APPENDIX I

(Bibliographies)

1. "Method of Describing The Detectivity of Photoconductive Cells", R. Clark Jones (Vol. 24, No. 11), The Review of Scientific Instruments.

2. "On The Relation Between The Speed Of Response And The Detectivity Of Lead Sulfide Photoconductive Cells", R. Clark Jones, (Vol. 43, No. 11), Journal of Optical Society of America.

3. "The Ultimate Sensitivity Of Radiation Detectors", R. Clark Jones, (Vol. 39, No. 5), Journal of Optical Society of America.

4. "Factors Of Merit For Radiation Detectors", R. Clark Jones, (Vol. 39, No. 5), Journal Of Optical Society of America.

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APPENDIX II

Table 1

Observer	Time (minutes)				
	No. 1	No. 2	No. 3	No. 4	No. 5
A	13:44.2	1:04.4	2:29.0	1:13.8	3:46.6
B	3:30.6	1:13.5	(12:53.8) (1:14.0)	5:38.1	2:24.6
C	1:41.5	1:02.6	1:08.6	1:24.0	0:42.5
D	2:35.5	1:48.0	(7:21.0) (0:31.8)	1:08.4	4:09.8
E	0:40.0	4:37.6	2:54.4	2:41.3	2:18.4
F	0:21.2	0:22.2	1:27.8	1:11.2	0:21.7
G	1:02.8	0:32.0	0:51.6	0:09.6	1:31.2

Average = 1 minute 37.6 seconds discounting the following readings:

13:44.2, 12:53.8 and 7:21.0

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